How Does Canopy Structure Influence Canopy Reflectance? A Experiment Based on Radiative Transfer Simulation and airborne lidar

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Motivation/Objective/Questions

Leaf/ground optical properties

Canopy structure

Others (geometry, light)

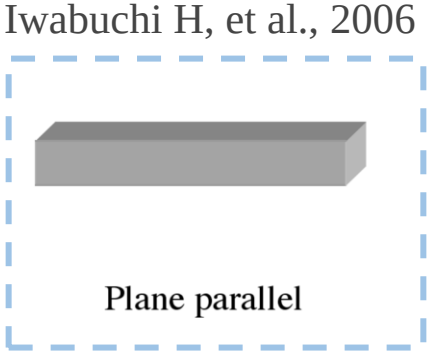
Canopy RTM

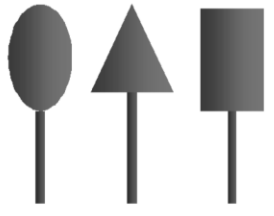
Canopy energy budget

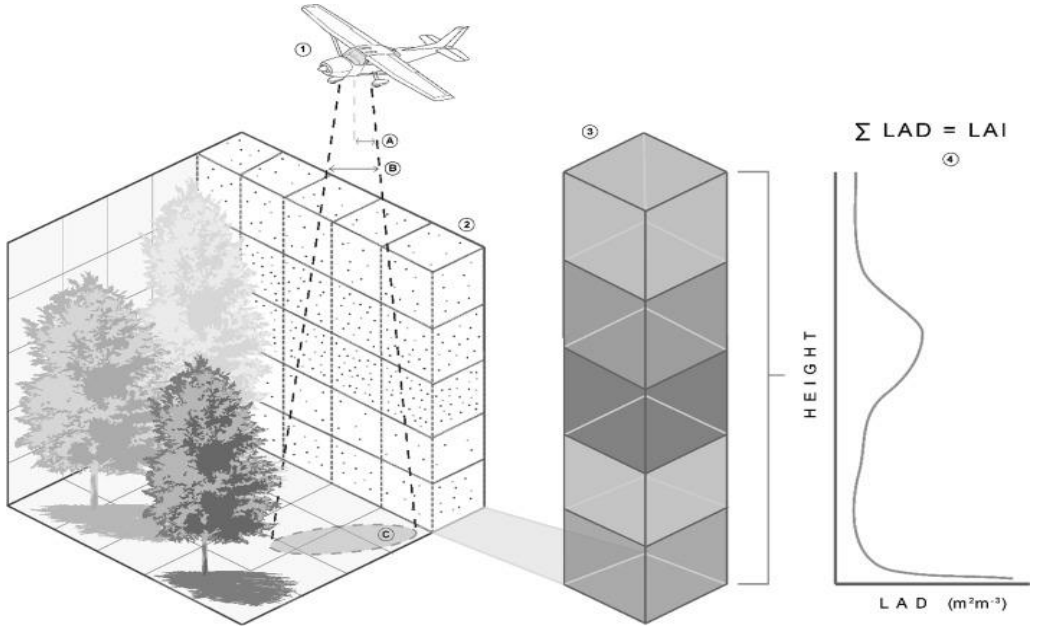
Land-atmosphere fluxes

Microclimate

Iwabuchi H, et al., 2006







Voxelization, Kamoske, A. G., et al., 2019

The Ultimate Question: To achieve realistic simulation of the canopy radiation regime and photosynthesis at the canopy scale, how much level of within-canopy heterogeneity do we need?

-- experiment with NEON airborne data and a 3D canopy radiative transfer model (FLiES; Kobayashi & Iwabuchi 2008)

Questions 0: parameter sensitivity

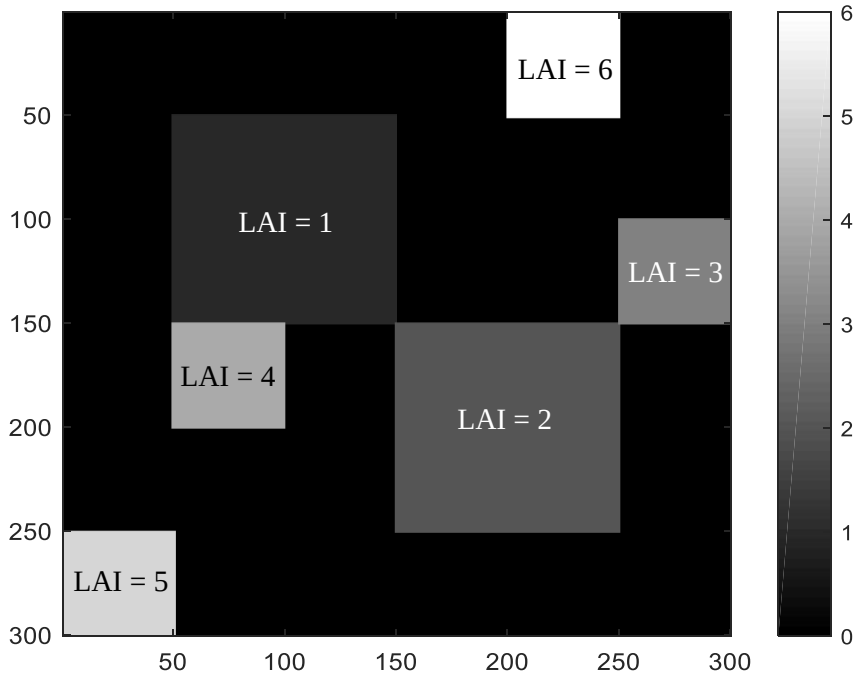
Forest Light Environment Simulator (**FLiES**; Kobayashi & Iwabuchi 2008)

Canopy structure

- Vegetation area density
- Wood ratio
- Leaf angle distribution
- Clumping index

Optical properties (Fixed)

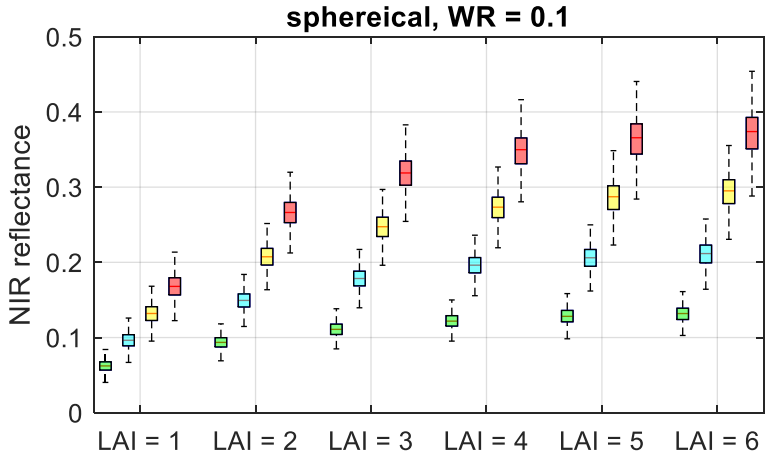
- Wood reflectance
- Leaf reflectance
- Leaf transmittance
- Litter floor reflectance

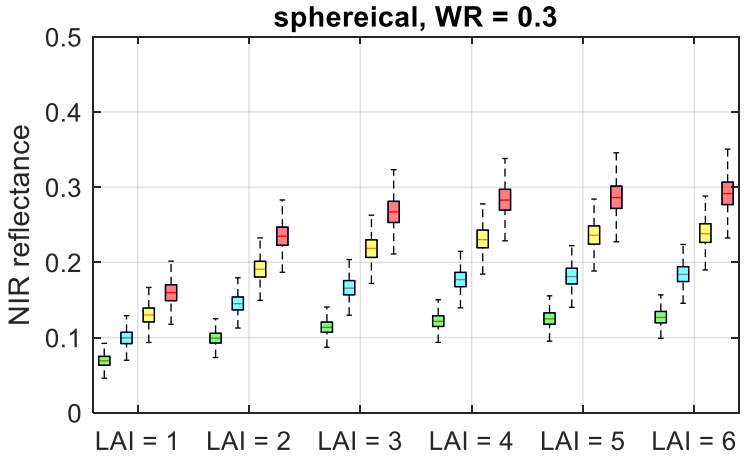


Leaf angle distribution	Spherical/Planophile
Woody ratio	0.1, 0.3
Clumping index	0.4, 0.6. 0.8, 1.0
Leaf reflectance	0.45
Leaf transmittance	0.45
Wood reflectance	0.2
Soil reflectance	0.01

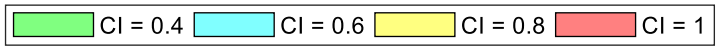
Scenario 1: Fixed Leaf Area Density value ($0.5\ m^2/m^3$)

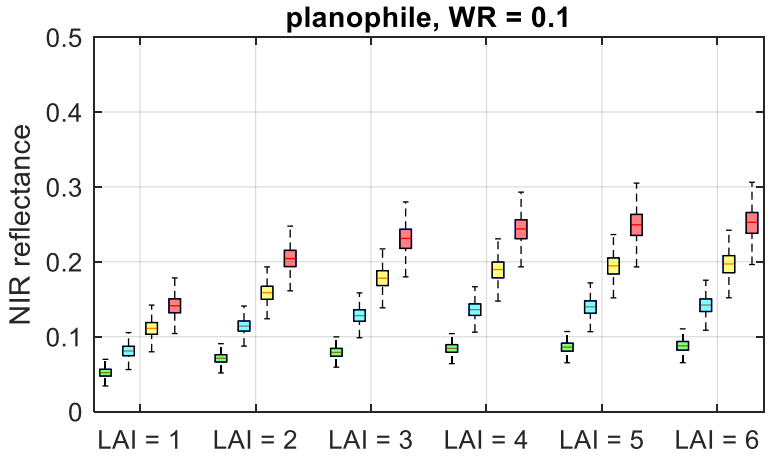
Spherical

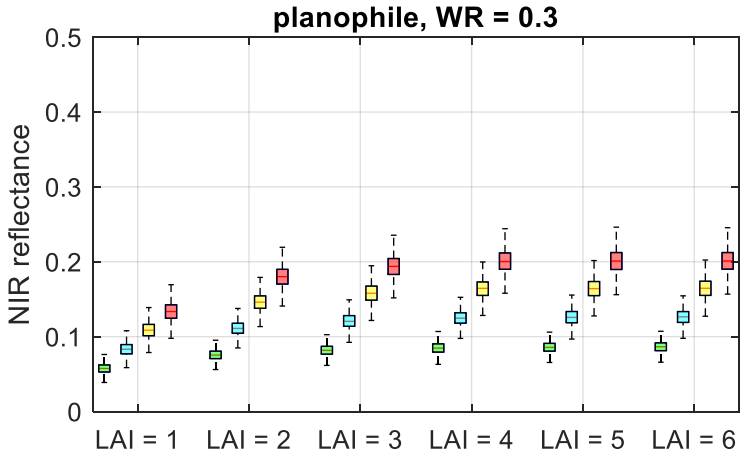




Planophile







WR = 0.1

WR = 0.3

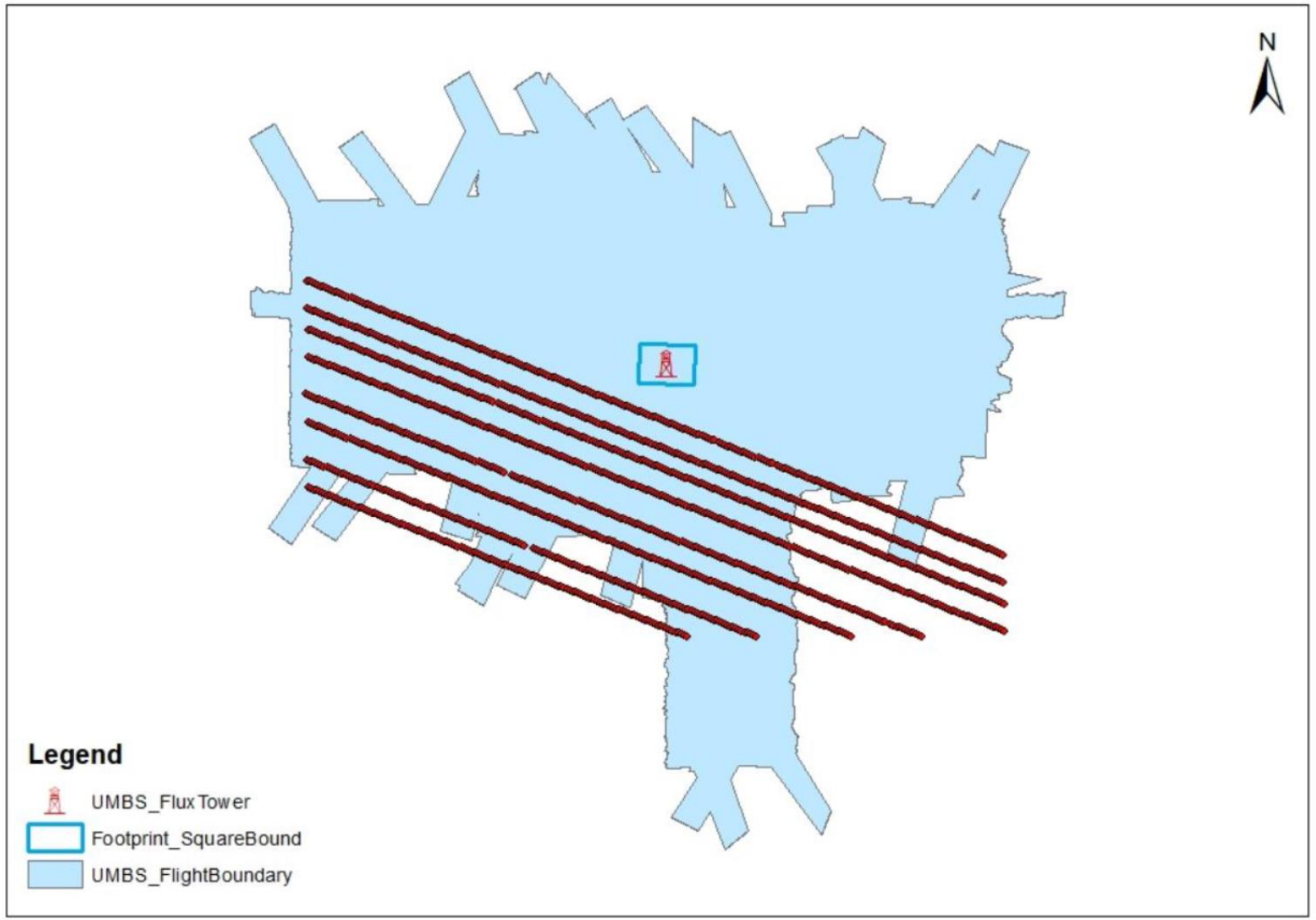
- Fixed LAD value given canopy height and LAI
- Spherical vs. Planophile
- Woody ratio $\propto {\rho_{NIR}}^{-1}$
- Clumping index
- ρ_{NIR} saturates slower at less clumped canopy
- The pattern is consistent across different types of LAD vertical profile.

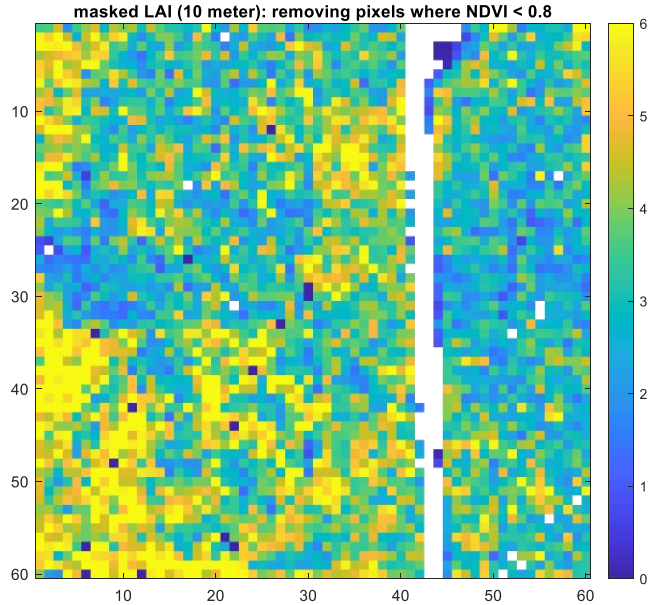
Specific Questions

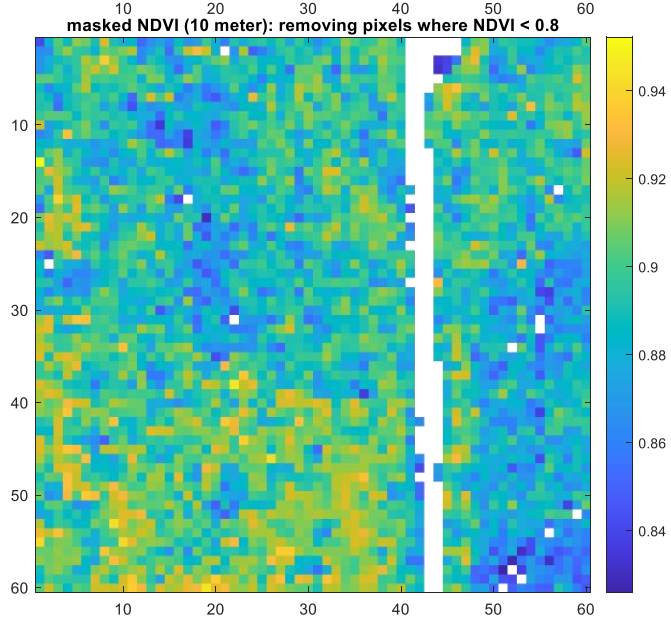
1. **Model calibration:** which combination of parameter values can regenerate the observed reflectance best?
2. How does **understory** matters?
   - Removal of the bottom 4-meter layers due to LiDAR uncertainty
   - With/without a homogenous understory (assume understory LAI = 2)
3. How does the **vertical details** of foliage distribution matters?
   - Full 3-D LAD canopy structure
   - Simplification: LAI + canopy height -> vertically even LAD profile
4. Is top of canopy reflectance sensitive to **different types of LAD profiles**?
   - Fixed canopy height: 24-meter
   - Designed various types of LAD profiles

- **Methods:** feed the FLiES model with real measurements instead of fake canopies (airborne/field measurements)

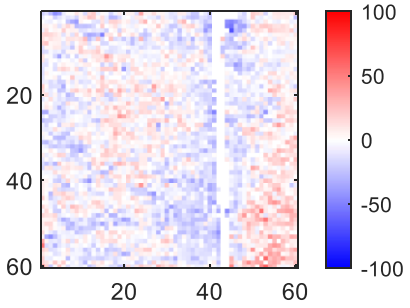
Study Area: UMBS (flux tower, 600m)

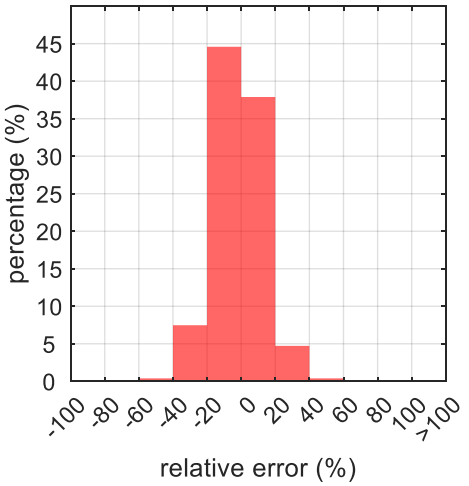


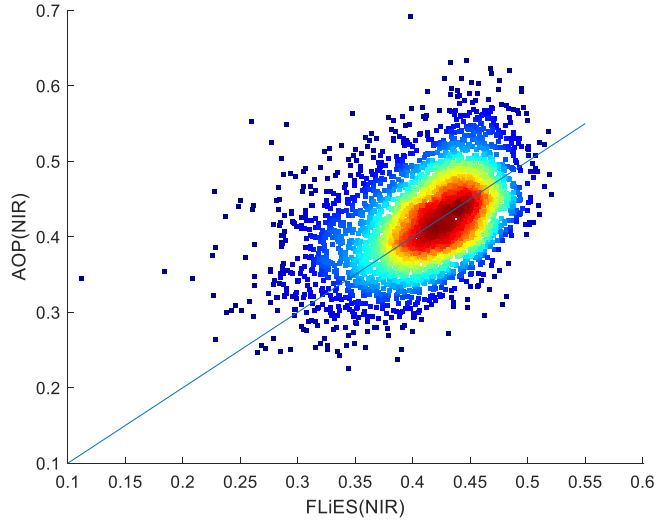


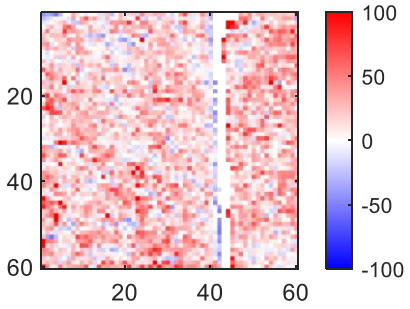


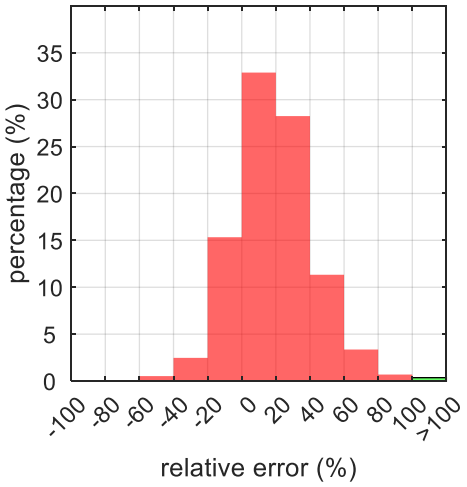
Question 1: model calibration

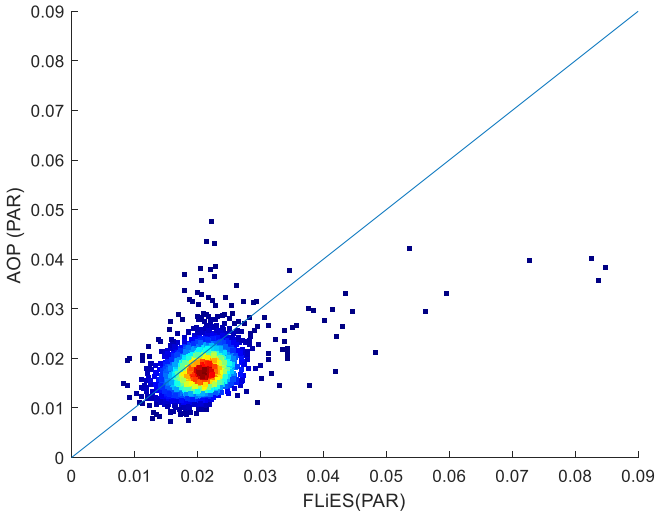












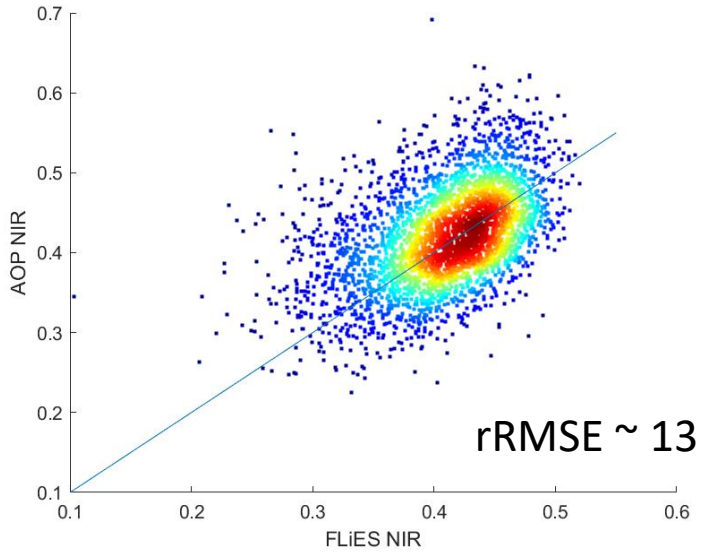
Optimal combination: CI = 1 + WR = 0.1 + spherical leaf angle distribution

Question 2+3: understory (LAI = 2) and vertical simplification

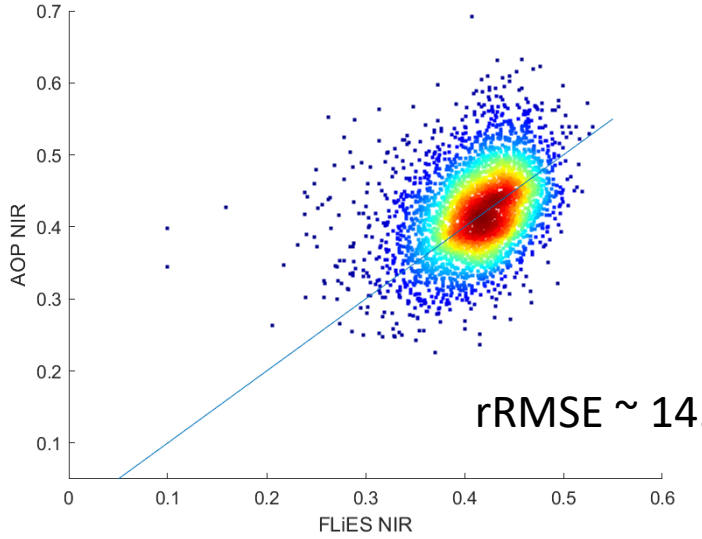
Full 3D LAD profile

Assume vertically even

Understory removed

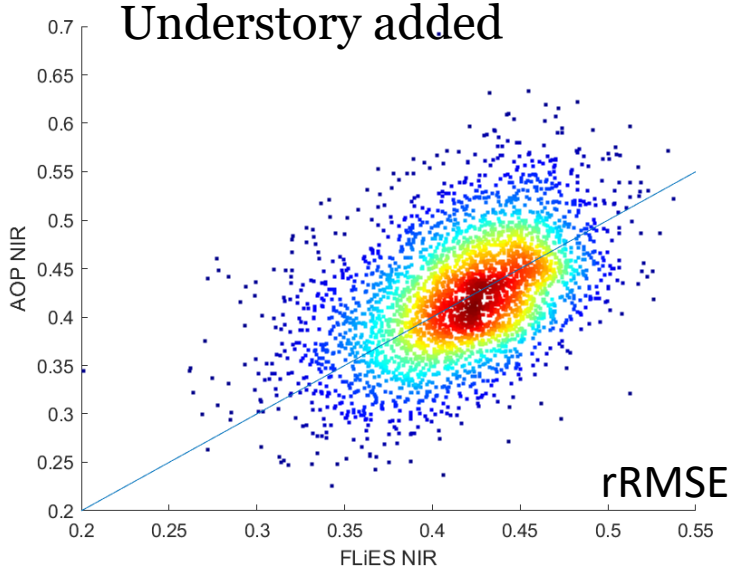


rRMSE ~ 13.9%

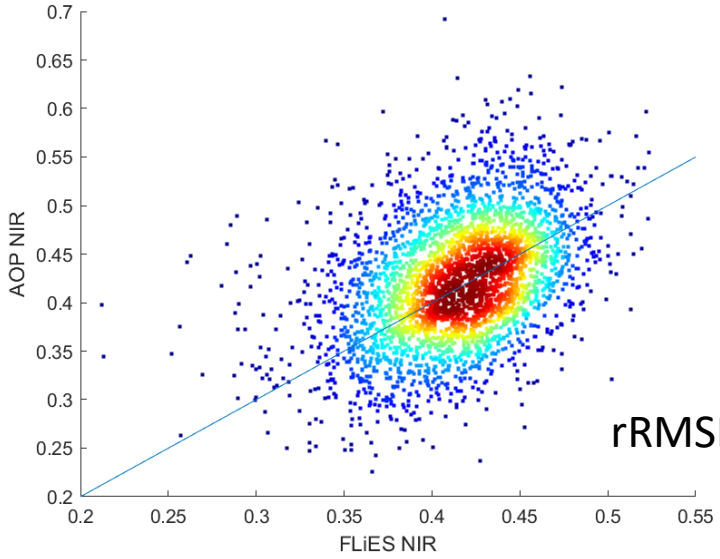


rRMSE ~ 14.2%

Understory added

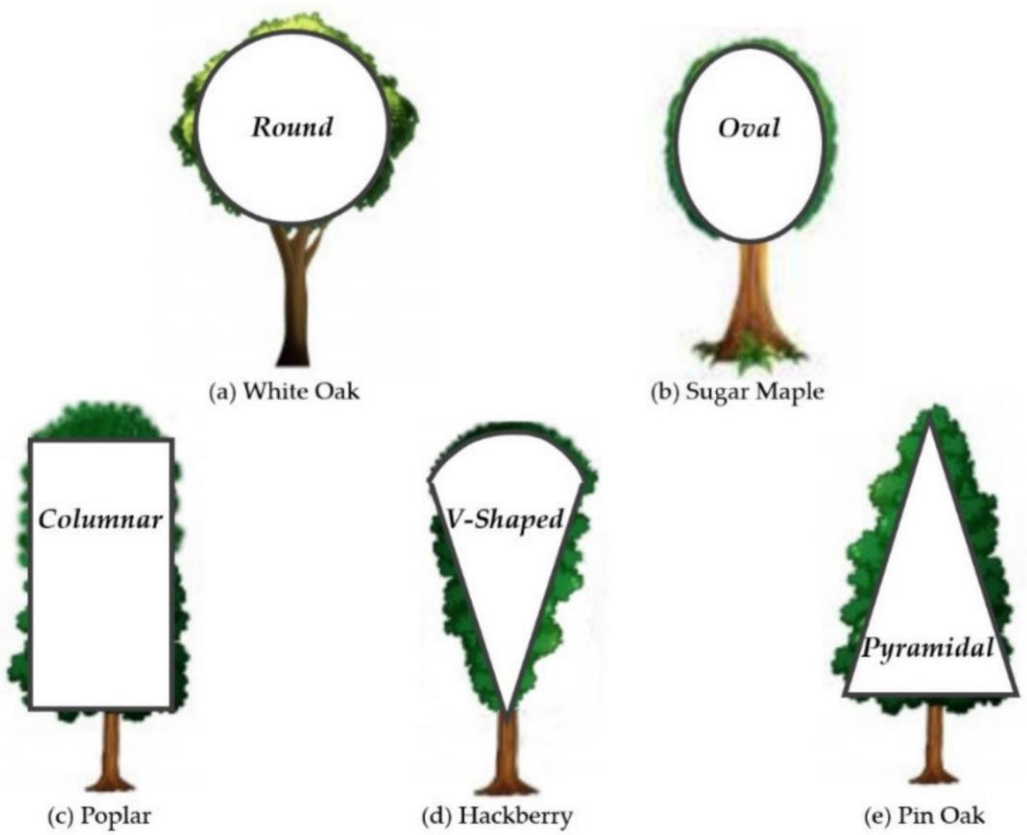


rRMSE ~ 13%

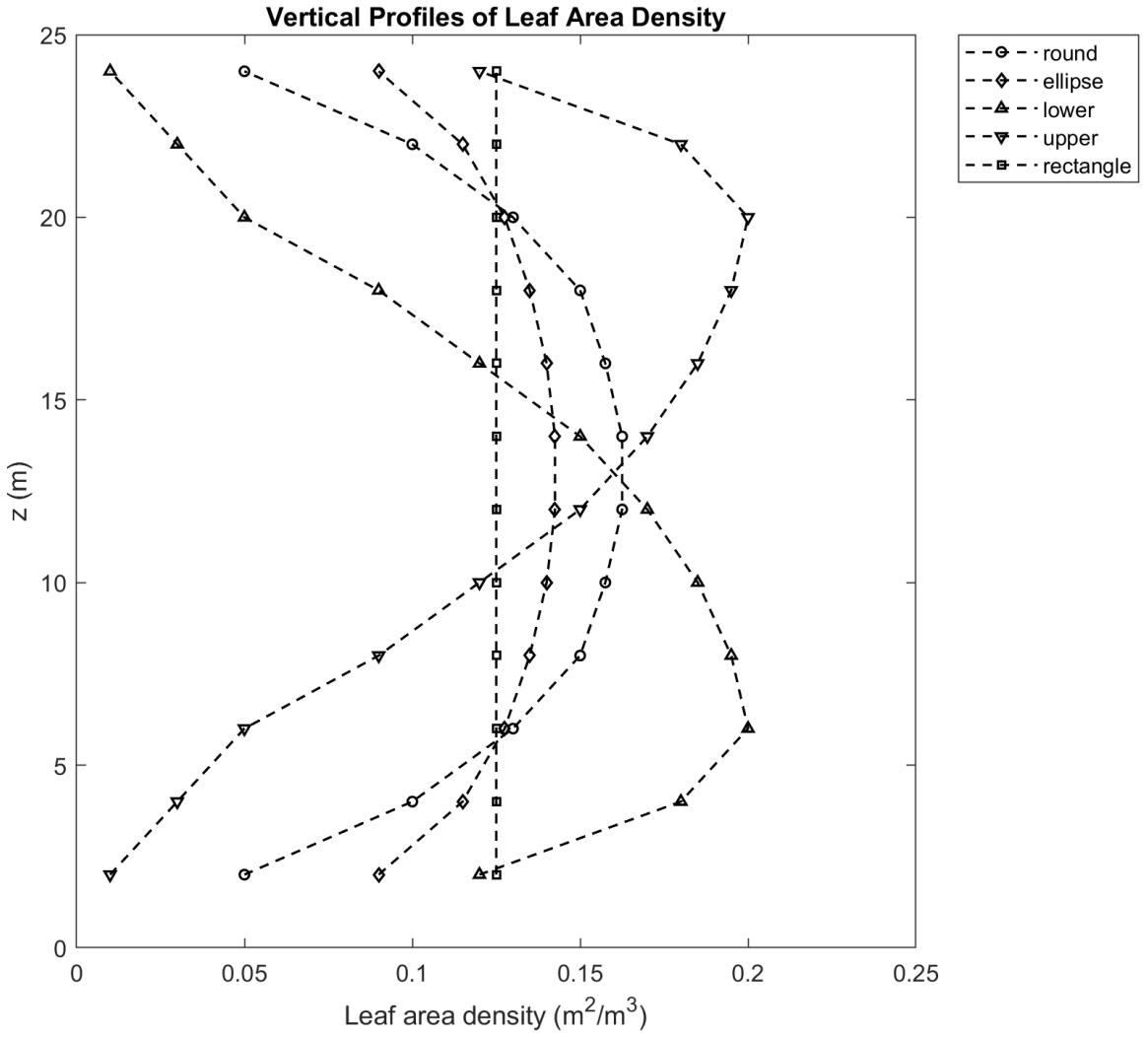


rRMSE ~ 13.7%

Question 4: different types of LAD vertical profiles



Liu, Xiangchen, et al., 2021



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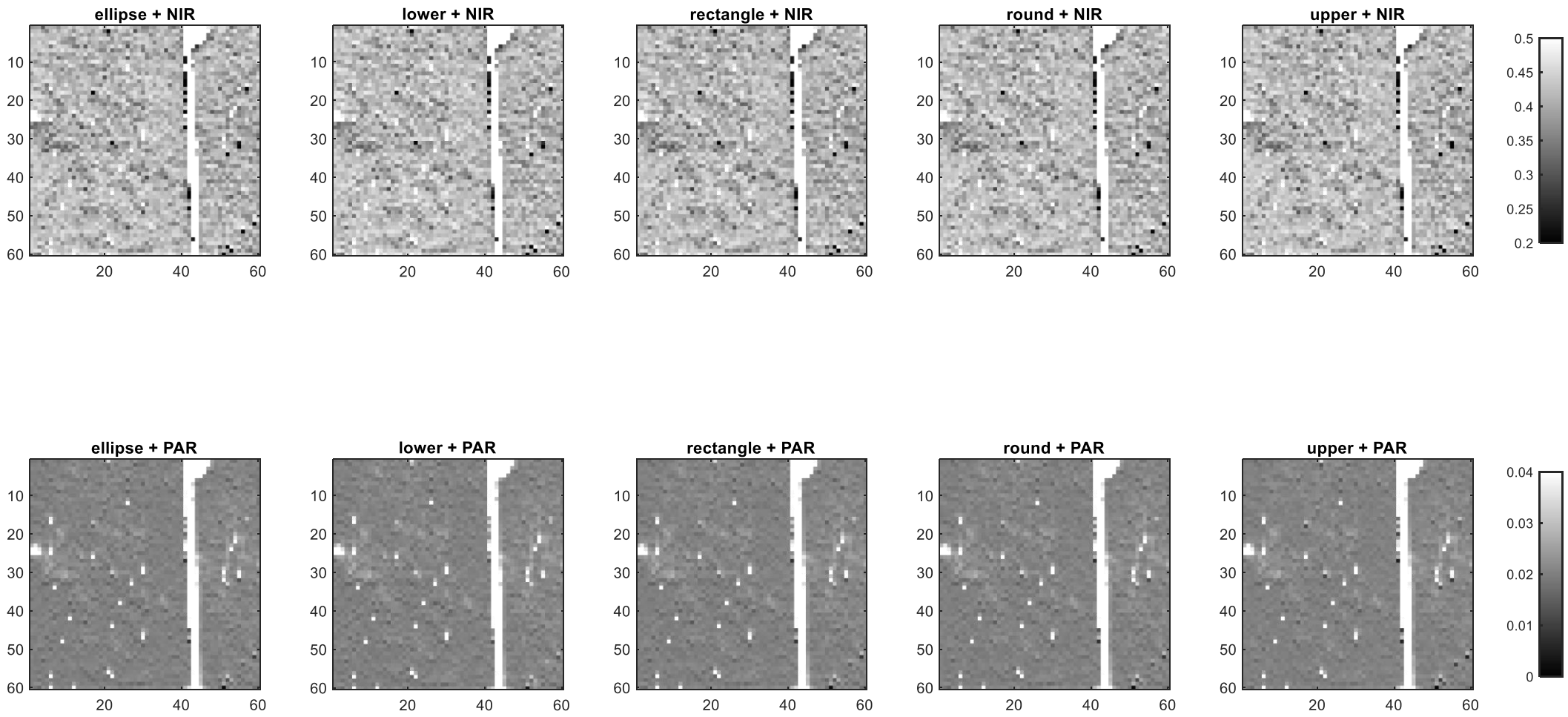

No much difference between LAD profile types

→ loss the canopy height information or

→ the radiation is not sensitive to vertical details of LAD?

Summary + Next step

- **How the canopy structure influences the top of canopy reflectance at the NIR/PAR band:**
  1. High sensitivity to clumping index, leaf angle distribution and wood/leaf ratio.
  2. **Measuring/estimating these variables is hard but necessary for better parameterization of 3D RTM.**
  3. The understory layer contributes to the top of canopy reflectance as well.
  4. **Sensitivity to the types of LAD vertical profile is lower than our expectation.** However, we only test scenarios where the trees across the whole landscape share the same type of LAD vertical profile and fixed canopy height.
- **Future experiment:**
  1. Different types of LAD vertical profile + canopy height
  2. Evaluation of simulated transmitted light with ground-based measurements (bottom boundary at the plot-scale)
  3. Canopy structure + leaf optical properties -> canopy radiation
  4. Coupling with photosynthesis models for GPP estimation


Thank you @/*\@ ~